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(54) Subject of Invention

Fiber Drawing Furnace for Optical Fiber

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DETAILED DESCRIPTION

1. Subject of Invention

Fiber drawing furnace for optical fiber

2. Scope of the Patent Claim

(1) A fiber drawing furnace for optical fiber characteristically comprises of the following: A furnace core tube in which an optical fiber preform is to be inserted and an inert gas is being flowed downward; a heater which surrounds the above furnace core tube to heat the aforementioned optical fiber preform; a cooling tube which is set up in succession to the bottom end of the aforementioned furnace core tube and to this tube, a cooling medium for cooling the aforementioned inert gas is provided; and a shutter, having a small hole at the center portion for the optical fiber to pass through, is attached between this cooling tube and the bottom end of the aforementioned furnace core tube.

(2) A fiber drawing furnace for optical fiber characteristically comprises of the following: A furnace core tube in which an optical fiber preform is to be inserted and an inert gas is being flowed downward; a heater which surrounds the above furnace core tube to heat the aforementioned optical fiber preform; a cooling tube which is set up in succession to the bottom end of the aforementioned furnace core tube and to this tube, a cooling medium for cooling the aforementioned inert gas is provided; a shutter, having a small hole at the center portion for the optical fiber to pass through, is attached between this cooling tube and the bottom end of the

aforementioned furnace core tube; and a diffuser which is set up at the bottom portion of the aforementioned ~~cooling tube~~ to blow an inert gas into the ~~cooling tube.~~

3. Detailed Explanation of the Invention

<Industrial Application Fields>

The present invention is related to an optical fiber fiber-drawing furnace which can manufacture a high quality optical fiber with little outside diameter variation; and the furnace is superior in durability.

<Conventional Technology>

The cross section structure of an example of the conventional optical fiber drawing furnace is shown in Fig 3. This fiber drawing furnace is equipped with a cylindrical furnace core tube 2 made of graphite etc. heat resistant material at the center portion of the metal square body 1; the center portion of this furnace core tube 2 is surrounded by the carbon heating element 3; and the space between the furnace core tube 2 and the outer circumference of the carbon heating element and the inside of the square body 1 is filled with heat insulating material. Furthermore, the optical fiber preform 8 is inserted from the top end of the furnace core tube 2; it is then heat-melted at the center portion of the furnace by the carbon heating element 3, fiber drawn into the optical fiber 11 and pulled out to outside from the bottom end of the furnace core tube 2. At the top end of the furnace core tube 2, the top portion diffuser 5, which is in ring shape and concentric to the furnace core tube 2, is set up to introduce an inert gas from

the introduction opening 7; a plural number of blowoff mouths 6, which will blow in the inert gas against the outer circumference, with slight tilt toward the bottom direction, of the optical fiber preform 8 being inserted along the inside wall of the top diffuser 5, are provided in the inside wall of the top portion diffuser 5. The inert gas blown-in from the blowoff mouth 6 will flow around the optical fiber 8 inside the furnace core tube 2 and move downward and be exhausted to outside of the tube from the pulling out opening 13 at the bottom end of the furnace core tube 2; and simultaneously a portion of the inert gas will be released upward along the outer circumference of the optical fiber preform 8 to prevent any flowing of the air into the furnace core tube.

Furthermore, at the pulling out opening 13 of the bottom end of the furnace core tube 2, the bottom portion diffuser 9, in ring shape and concentric to the furnace core tube 2, is provided. To the inside of the bottom portion diffuser 9, an inert gas is also introduced from outside, and a plural number of nozzles, 10, having opening on the inside wall face of the bottom portion diffuser 9 are provided. From these nozzles 10, the inert gas is blown against the optical fiber 11 in the downward direction to prevent the entry of the air into the furnace core tube 2. And a portion of the inert gas blown off from the nozzles 10 will flow upward of the furnace core tube.

As described before, the optical fiber preform 8 is delivered vertically by an equipment not shown in the figure into the the inside of the furnace core tube 2 which is, for

example, heated to about 2100°C, to become optical fiber 11; the fiber is then wound by a winding equipment not shown in the figure.

<The Problems to be Solved by the Present Invention>

In the optical fiber drawing furnace, among the required performance, the important items include the stability of the outside diameter of the optical fiber 11, the extremely clean condition, and that the inside furnace is filled with inert gas to prevent the oxidation damage by the invasion of the air.

In the conventional optical fiber drawing furnace shown in Fig 3, the bottom portion diffuser 9 is arranged at the bottom end of the furnace core tube 2; a portion of the low temperature inert gas blown off the bottom portion diffuser 9 will ascend the high temperature furnace core tube 2 inside, and this gas will be violently mixed with the inert gas, which has been blown down from the top portion diffuser 5 and heated to high temperature in the furnace, to create a turbulent flow.

Meanwhile, a small interval of the optical fiber 11 being drawn down from the molten tip portion 12 of the optical fiber preform 8 delivered into the furnace core tube 2 will maintain a molten-softened condition; this portion is then immediately cooled-solidified to form the final outside diameter of the optical fiber 11 and pulled down to outside of the furnace core tube 2. In this situation, at the molten-softened portion of the optical fiber 11 pulled from the molten-tip portion 12 of the optical fiber preform 8, before it is cooled-solidified, the aforementioned turbulent flow by the vigorous mixing of the high

temperature inert gas blown down from the top and the cool inert gas blown up from the bottom will occur. The uneven temperature of this turbulent flow will influence the final outside diameter formation of the optical fiber 11 to cause variation. Moreover, by the high temperature inert gas being blown down from the top, even at the the vicinity of the pulling out opening 13 of the bottom portion diffuser 9, the temperature will stay high; thus to this portion, the cool air (from outside) will enter the inside of the tube. And the air entered will become an ascending current and this will severely damage the inside of the furnace core tube 2. The oxidation reaction products will adhere to the optical fiber 11 and become a cause for lowering the strength of the optical fiber 11.

The present invention was undertaken in view of the above described various defects in the conventional optical fiber drawing furnace. It is aimed to provide an optical fiber drawing furnace which can prevent the mixing of the air into the fiber drawing furnace to manufacture superior quality optical fibers.

<The Means Used to Solve the Problems>

The first fiber drawing furnace for optical fiber of the present invention is characteristically comprises of the following: A furnace core tube in which an optical fiber preform is to be inserted and an inert gas is being flowed downward; a heater which surrounds the above furnace core tube to heat the aforementioned optical fiber preform; a cooling tube which is set up in succession to the bottom end of the aforementioned

furnace core tube and to this tube, a cooling medium for cooling the aforementioned inert gas is provided; and a shutter, constructed in 2 divided portions to have a small hole at the center portion for the optical fiber to pass through, is attached between this cooling tube and the bottom end of the aforementioned furnace core tube. And, the second fiber drawing furnace for optical fiber of the present invention is characteristically that in addition to the first invention construction, at the bottom portion of the aforementioned cooling tube, a diffuser which will blow in an inert gas is equipped.

<Function>

The optical fiber being fiber drawn from the bottom end of the optical fiber preform delivered from the top end of the furnace core tube is surrounded by an inert gas provided from the upper part. This inert gas will be heated to high temperature inside the furnace core tube, but it will be cooled in the cooling tube; thus at the bottom end (of the tube), the temperature difference between this gas and the atmospheric temperature will be negligible. Therefore, no atmospheric air will flow into the furnace core tube from the bottom end of the cooling tube. Furthermore, by the shutter arranged between the furnace core tube bottom end the cooling tube, the heating of the cooling tube by the radiation heat from the furnace core tube high temperature portion will be prevented to enhance the cooling effect of the cooling tube.

<Implementation Example>

The cross section structure of an implementation example of the optical fiber drawing furnace based on the present invention is shown in Fig 1; and the cross section shape of the portion indicated by the II - II arrow signs in the figure is shown in Fig 2. As shown in Figure 1, the fiber drawing furnace is equipped with a cylindrical furnace core tube 2 made of graphite etc. heat resistant material which is located at the center portion of the metal square body 1. The center portion of the furnace core tube 2 is surrounded by the carbon heating element 3 to maintain a high temperature. The inside of the square body 1, which surrounds the furnace core tube 2 and the carbon heating element 3, is filled with the heat insulating material 4. And At the top end of the furnace core tube 2, the diffuser 5, which is in ring shape and concentric to the furnace core tube 2, is connected. The inert gas introduced from the introduction entrance 7 is blown off the blowing opening 6 in slightly downward direction.

Further, at the bottom end of the furnace core tube 2, beneath the shutter 24 having a small hole for allowing the optical fiber 11 to pass, the cooling tube 14 which is concentric to the furnace core tube 2 and cooled by water etc. cooling medium is connected. In the outside tube 17 of the cooling tube 14, the cooling water flowing-in entrance 19 and the exit 20 are provided to cool the cooling tube 14 to a specified temperature. And, the tapered portion 15 formed in the top inner circumference face of the cooling tube is such that its top end is roughly equal to the inside diameter of the furnace

core tube 2 and the bottom side is gradually reduced in diameter. This is then connected to the inside tube 16 of L length required for cooling the high temperature inert gas to a specified temperature, for example, 100°C. The inside diameter of this inside tube 16 is tapered to narrower shape from the inside diameter which is roughly equal to that of the furnace core tube 2. Because of this, the disturbance of the inert gas flow is prevented and additionally the cooling effect is enhanced. At the bottom end of the cooling tube 14, the diffuser 22 of inert gas surrounding the inside tube 16 is provided in unibody. It is constructed that the inert gas introduced from the inert gas introduction entrance 21 formed on this diffuser 22 is blown off from the plural number of blowing-off mouths 23 provided around the inside tube 16 in the direction toward the center of the inside tube 16.

From the top end of the furnace core tube 2 of the fiber drawing furnace, the optical fiber preform 8 is concentrically introduced ; the optical fiber preform 8 is heat-melted at the high temperature portion created by the carbon heating elements 3 at the furnace core tube 2 center; and it is fiber drawn at a specified fiber drawing speed into the optical fiber 11 having a specified outside diameter. The fiber drawn optical fiber 11 passes through the cooling tube 14 and pulled to outside from the bottom end of the cooling tube 14. During this, from the blowoff mouth 6 of the diffuser 5 set up on the top end of the furnace core tube 2, an inert gas is provided downward to pass through the space between the optical fiber preform 8 and the

diffuser 5 to prevent the entering of the air into the furnace core tube 2, and simultaneously the circumference of the optical fiber preform 8 is surrounded by the downward stream of the inert gas to protect the furnace core tube 2 against oxidation. The inert gas provided to the furnace core tube 2 will become high temperature at the high temperature portion, but as it descends from the tapered portion 15 of the cooling tube 14 connected to the bottom end of the furnace core tube 2 to the inside tube 16, it will be continuously cooled to reach the necessary temperature and then released to the outside from the bottom end of the cooling tube 14. The temperature of the inert gas at the time of being released from the bottom end of the cooling tube 14 is lowered roughly to the atmospheric temperature by the cooling tube 14. Because of this, there will be no heat convection based on temperature difference at the bottom end of the cooling tube 14. Therefore, there will be no worry for the air to enter the inside of the cooling tube 14. Moreover, by the inert gas diffuser at the bottom end of the cooling tube 14, an inert gas is blown off from the blowing mouth 23, which is opened at the circumference of the inside tube 16 of the diffuser 22, to completely shut off the invasion of the air from the bottom end of the cooling tube 14. And by setting up the shutter 24 as shown in Fig 2 between the furnace core tube 2 and the cooling tube 14, the radiation heat from the high temperature portion of the furnace core tube 2 is shielded to further enhance the cooling efficiency of the inert gas in the cooling tube 14. Furthermore, because the inside diameter

of the small hole 25 provided on this shutter is rather small, for example 5 mm, the shutter is constructed so that the two parts can be slided in left-right (horizontal) direction of Fig 2 to let the chip (falling seed) formed at the start of the optical fiber 11 fiber drawing to pass through.

<Implementation Example>

In the equipment shown in Fig 1 and Fig 2, the effective cooling length L of the cooling tube 14 was made 50 cm; the inside diameter of the cooling tube 14 was made 2 cm; and for the inside tube 16 of the cooling tube 14, a 3 mm thickness copper tube was employed. The temperature of the cooling water in the cooling tube was maintained at 20°C, and the diameter of the small hole 25 of the shutter 24 was set at 5 mm. In the case when the diffuser 22 was not attached to the bottom end of the cooling tube 14, the inert gas flow rate flowing down from the furnace core tube to the cooling tube 14 was set at 5 liter/minute. And when the temperature was about 1000°C, the temperature of the released gas at the bottom end of the cooling tube 14 became 120°C, and the oxygen concentration at the vicinity of the bottom end of the furnace core tube 2 was 100 ppm which is a drastic improvement over the 300 ppm oxygen concentration in the conventional approach. Furthermore, the outside diameter variation of the formed optical fiber 11 was $\pm$ 0.5 μm.

Meanwhile, when the diffuser 22 was attached to the cooling tube 14, and 5 liter/minutes of nitrogen was blown into the system from the diffuser 22, the oxygen concentration at the

bottom end of the furnace core tube 2 was further lowered to 50 ppm in employing the identical conditions of the aforementioned example. And, the outside diameter variation of the formed optical fiber was also $\pm$ 0.5 μm; no influence to the the outside diameter by the blowing-in inert gas was recognized.

Further, the life of the furnace inside parts was prolonged to about 2 weeks in the present invention, compared to about 1 week in the conventional approach.

<Effect of the Invention>

According to the optical fiber fiber drawing furnace of the present invention, by providing a cooling tube to surround the optical fiber at the bottom end of the fiber drawing furnace, the temperature of the inert gas to be released into the atmosphere from the cooling tube bottom end became lower and the invasion of the air into the system by the temperature difference between the inside and outside of the cooling tube became extremely small. As a result, the wear and tear of the inside of the furnace core tube became much less, and the life of the furnace core tube was drastically prolonged. Furthermore, there was no temperature unevenness caused by the disturbance of the inert gas flow inside the furnace core tube, the flow of the inert gas was stabilized. Because of this, no outside diameter variation (of the fiber) occurred, and the manufacturing of optical fiber superior in quality with uniform outside diameter became possible. Moreover, by providing a diffuser at the bottom end of the cooling tube, the invasion of the air from the outside was shut off more

completely to further decrease the wear and tear of the inside of the furnace core tube. In addition, by providing a shutter between the fiber drawing furnace and the cooling tube, the efficiency of the cooling of the inert gas flowing down was further improved.

4. Brief Explanation of Figures

Fig 1 is the cross section diagram of an implementation example of the optical fiber drawing furnace based on the present invention. Fig 2 shows the cross section diagram of the portion indicated by II-II in Fig 1. Fig 3 is a cross section diagram of the conventional optical fiber drawing furnace.

In the figures, 1 is square body; 2 furnace core tube; 3 carbon heating element; 4 heat insulating material; 5 and 22 diffuser; 6 blowing mouth; 7, 19 and 21 introduction entrance; 8 optical fiber preform; 11 optical fiber; 14 cooling tube; 15 tapered portion; 16 outside tube; 17 inside tube; 20 and 23 exhaust opening; 24 shutter; and 25 small hole.

Fig 1

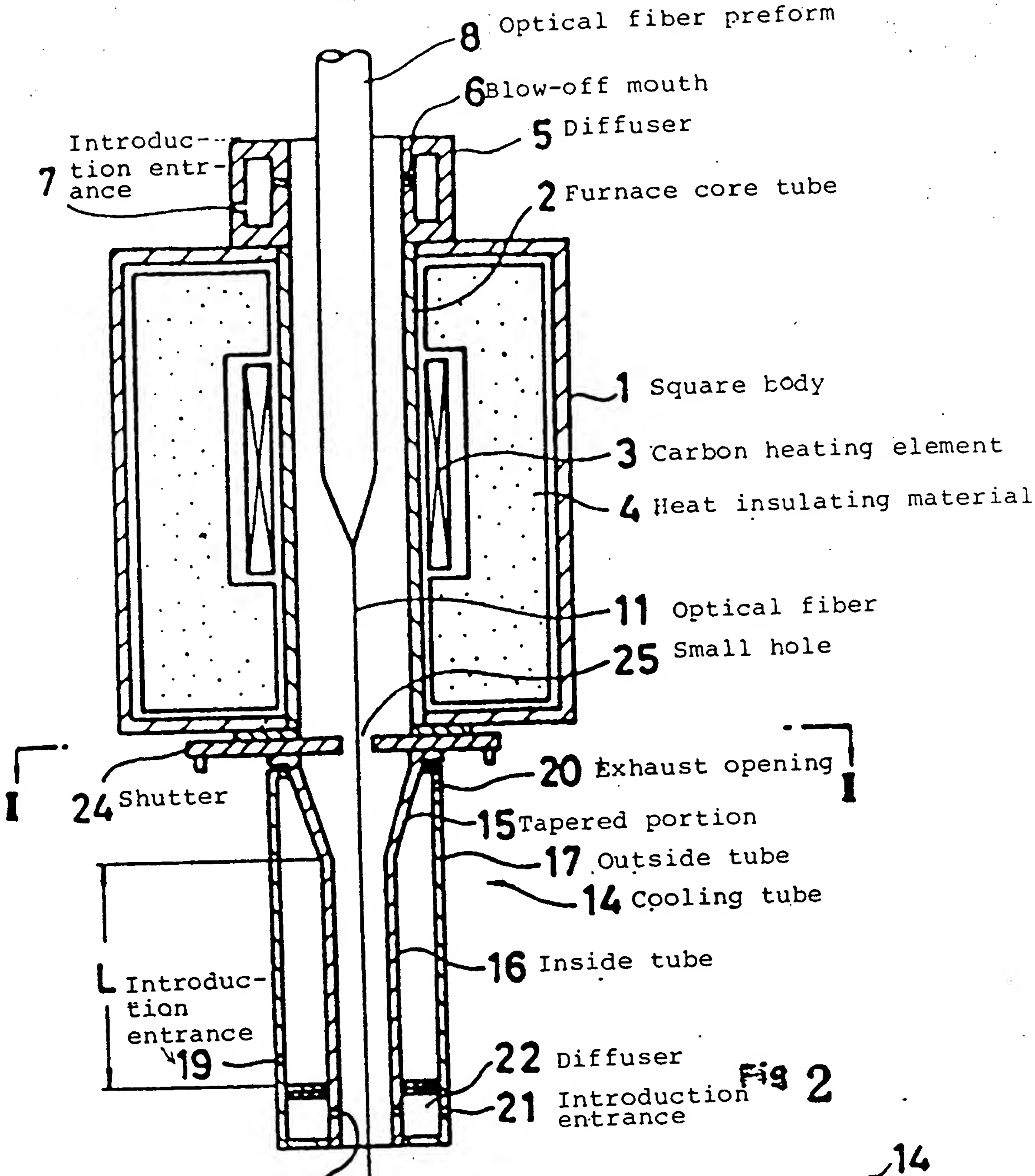
8 Optical fiber preform
6 Blow-off mouth
5 Diffuser
7 Introduction entrance
2 Furnace core tube
1 Square body
3 Carbon heating element
4 Heat insulating material
11 Optical fiber
25 Small hole
20 Exhaust opening
I
I
24 Shutter
15 Tapered portion
17 Outside tube
14 Cooling tube
16 Inside tube
L Introduction entrance
19
22 Diffuser
21 Introduction entrance
23
Blow-off opening

Fig 2

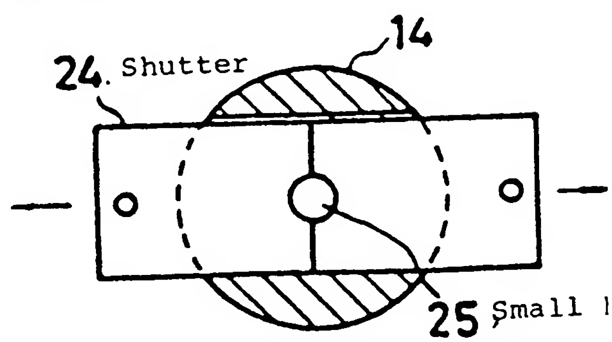
14
24 Shutter
25 Small

Fig 3